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ABSTRACT

A selective review of literature related to individual differences and instructional strategies is presented. The major purpose is to give the reader a flavor of the kind of thought that is currently prevalent and the type of research that is being conducted in selected areas. No attempt is made to provide either a comprehensive or a balanced treatment. Rather, studies illustrative of certain trends have been selected and included under one of six broad areas: theories of instruction, trait-treatment interaction analysis, learner control of instruction, adaptive instructional models, training of learner traits and strategies, and designing instructional tasks. Some integration of the six areas is attempted. (Author)

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INSTRUCTIONAL STRATEGIES AND INDIVIDUAL DIFFERENCES:

A SELECTIVE REVIEW AND SUMMARY OF LITERATURE

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Summary

A selective review of literature related to individual differences and instructional strategies is presented. The major purpose is to give the reader a flavor of the kind of thought that is currently prevalent and the type of research that is being conducted in selected areas. No attempt is made to provide either a comprehensive or a balanced treatment. Rather, studies illustrative of certain trends have been selected and included under one of six broad areas: theories of instruction, trait-treatment interaction analysis, learner control of instruction, adaptive instructional models, training of learner traits and strategies, and designing instructional tasks. Some integration of the six areas is attempted.

Introduction

The goal of the Advanced Research Projects Agency's (ARPA) Advanced Training Technology Program is to accelerate the application of training technology in the Services of the Armed Forces. To accomplish that end, research requirements have been considered and categorized in five distinct areas (Hickey, 1975). One of these areas is "Individual Differences and Instructional Strategies." It is the purpose of this paper to present selected illustrative research and to summarize the general mood with respect to several topical areas subsumed under the broader area of instructional strategies and individual differences. In treating the topics to be presented--theories of instruction, trait-treatment interaction analysis, learner control of instruction, adaptive instructional models, training or modification of learner traits and strategies, and designing instructional tasks--no attempt to provide a comprehensive review of literature will be made. Rather studies felt to be illustrative of important trends will be emphasized, as will the thinking of recognized authorities in various areas. Each section has a distinct flavor of computer-assisted instruction, although preservation of a more general orientation has been attempted.

I. Theories/Models/Principles of Instruction/Learning

Theory has been thought to play an important role in the development of any science. It is seen as useful, and perhaps essential, in directing empirical investigations and in integrating and ordering existing empirical laws (Marx, 1963). Psychology, like other sciences, has also been concerned with theory, attempting to develop and test theories of learning and instruction. (Bruner's (1964) distinction between the descriptive nature of a theory of learning and the prescriptive nature of a theory of instruction should be recalled.) While psychologists appeared to be making progress towards statements of rules, laws, or principles of learning (and to a lesser extent instruction), an increasing number of psychologists have contended recently that there has been some "backsliding." McKeachie (1974a), for instance, has observed that Thorndike's principles of learning seem to be "crumbling"--that knowledge of results may not be necessary, that delayed knowledge of results may be more effective than immediate knowledge, that rewards are not uniformly successful, that errors do not seem to persist as expected, that careful planning of learning programs may produce no better results than random sequences, that learning by small steps may be less effective than using large steps, and that defining objectives may not help student learning.

McKeachie concludes his review with an even stronger contention that

> each one of the principles confidently enunciated by Skinner in The Science of Learning and the Art of Teaching now turns out to be untrue--at least in as general a sense as he believed at that time.

Cronbach (1975) questions whether it is wise to even attempt to reduce behavior to laws.

McKeachie continues this theme in an article appropriately titled "The decline and fall of the laws of learning" (McKeachie, 1974b) in which he suggests that the familiar principles may hold only under limited conditions. He cites two reasons for this decline: (1) a failure to take into account differences between human and other animals (e.g., man's greater ability to conceptualize, relate, and remember), and (2) a failure to account for important variables which are controlled in laboratory situations but which interact with independent variables in natural settings.

Frase (1975) in his review of advances in research and theory in instructional technology agrees with McKeachie. After reviewing the areas of (1) structure of knowledge and skill domains, (2) management of instructional materials (3) management of learning activities, and (4) measurement of learning outcomes, he concludes that it is difficult to enumerate principles of instruction that apply directly to a wide variety of tasks and that:

> If instructional theory appears poorly articulated, and instructional development appears to be as much art as science, this is because no one theory or set of rules can be expected to encompass all of the relevant components of an instructional episode.

Considering the role of theory in future instructional development efforts, he asks:

> what can be said about the possibilities for a general instructional theory and consequently for the prescriptive rules that guide instructional development?

His answer:

> Perhaps the vision of a general theory is futile; what is needed is a series of small theories that deal with specific components of instruction.

In discussing the research of R. C. Atkinson and his staff, Beard, Barr, Fletcher, and Atkinson (1975) state their belief that any theory of instruction is measured against four criteria and that, to the extent that these four criteria can be formulated explicitly, optimal instructional strategies can be developed. These criteria entail (1) a model of the learning process, (2) specification of admissible instructional actions, (3) specification of instructional objectives, and (4) a measurement scale that permits costs to be assigned to instructional actions and payoffs to achievement.

Beard et al. (1975) believe that the methods they have developed do offer specifications for optimal procedures but that the first criterion listed above--specification of a model of the learning process--"represents a major obstacle" and that until we have a deeper understanding of the learning process, the identification of truly effective strategies will not be possible. They summarize the present state of the art by saying that:

> Our theoretical understanding of learning is so limited that only in very special cases can a model be specified in enough detail to enable the derivation of optimal procedures.

They argue, however, that an "all-inclusive" theory may not be necessary as long as we have a model that "captures the essential features of that part of the learning process being tapped by a given instructional task."

Glaser (1976) feels that the little we do know about learning is known in terms of descriptive science, but that we have not even used this information in designing the conditions of instruction. He cites the work on behavior modification, the work of Gagné, and the work on optimization models as notable exceptions, but even these attempts have not considered complex cognitive performance in any "intensive way." Earlier, Gagné (1971) summarized the ideas of four learning theorists--Miller, Skinner, Gagné, and Ausubel. Gagné believes that each of the four theories of learning espoused by these four psychologist has implications for the design of instruction but that

> Virtually no instructional materials, texts, or films in existence today have deliberately been prepared on the basis of these principles.

Three years later, Merrill and Boutwell (1973) were equally pessimistic about instructional development efforts, suggesting that they can be characterized by "raw empiricism" and that the basis for their preparation is "intuitions, folklore, or experience."

More recently, however, Leonard (1975) has implied that there have been changes in instructional design procedures. The three books on instructional design that he reviews (Davies, 1973; Gagné & Briggs, 1974; Snelbecker, 1974) are representative of a third generation of instructional design--a generation that is characterized by its more eclectic approach and the absence of allegiance to a single theory. While the first generation showed a strong Skinnerian influence resulting in "cookbooks" espousing operant conditioning as the means for "systematic design of uniformly effective instruction," the second generation design strategies were guided more by pragmatics than by a single learning theory and were characterized as having "little theoretical underpinning." Leonard's characterization of the third generation may be consistent with Beard et al.'s (1975) notion that an "all-inclusive" theory is unnecessary.

Mayer's (1975) approach seems to be illustrative of an attempt to specify a model(s) that is not all-inclusive, yet which captures what he believes to be the essential feature of the learning process necessary for a specific instructional task (problem solving). Mayer argues that most theories of instruction rely, implicitly or explicitly, on a model of the learner's internal processing system. Mayer attempts an explicit formulation, presenting three successively more complex models of internal processing in learning to solve problems.

In summary, one may get a general feeling from the views presented above that, while the theoretical foundations of instructional design are not well developed, there have been some noteworthy attempts to strengthen them. At the least a healthy skepticism and a realistic view of the state of the art seem to prevail.

II. Interaction of Learner Traits with Instructional Strategies

Glaser and Resnick (1972), in their attempt to provide a "momentary definition" of the field of instructional psychology, were struck by the convergence of the studies they reviewed on the analysis of performance in terms of the interactions between task structure variables and the learning and information processing capabilities of the individual. They believe that such an emphasis is "crucial" for an instructional psychology. This emphasis is considered in this section.

Glaser has also on two occasions (Glaser, 1972, 1976) discussed the differential development of the two major areas of scientific psychology--psychometrics and general experimental psychology. Idiosyncratic of the first area has been the emphasis on individual differences and their measurement, while the latter area has focused on formulating general laws of behavior without regard to individual differences, which have been considered to be error variance. Glaser (1976) speculates on the nature of a "linking science" and arrives at the following components of a psychology of instruction--components that he thinks comprise the information required to provide the link between theory and educational applications. These are:

(1) analysis of the competence, the state of knowledge and skill, to be achieved,

(2) description of the learner's initial state,

(3) conditions that can be implemented to bring about change from the learner's initial state to the desired state,

and (4) procedures to assess outcomes.

Areas (2) and (3) above are central to what has become known as aptitude treatment interaction* research--a line of investigation first advocated by Cronbach (1957) and later developed by Cronbach and his associates (e.g., Cronbach, 1967; and Cronbach & Snow, 1969). Increasing concern that consideration of individual differences is of fundamental importance in developing a psychology of instruction has resulted in the combing of studies to find interactions between learning variables and individual differences, oftentimes without much success (e.g., Bracht, 1970).

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*Berliner and Cahen (1973) have preferred the term "trait-treatment interaction." The less restrictive term "trait" includes personality, status, attitude, and interest variables.

Early considerations of the ATI concept urged designing enough treatments so that everyone would be able to succeed at one of them. The ATI line of research would be aimed at finding abilities and instructional variables and matching the two sets in order to achieve an optimal learning result. Cronbach (1975) reports more recently, however, that the line of research he first advocated "no longer seems sufficient" because interactions are not confined to the first order, but that dimensions of the situation and of the person enter into complex interactions. He feels that inconsistencies found in many studies of learning and instruction (and we might add theories) can be explained by recourse to higher order interactions. Winne (1976) notes this complexity of interactions in a study on teacher effectiveness, finding that aptitudes interacted not with treatment main effects but with one and sometimes two other dimensions of his analysis.

Berliner and Cahen (1973) believe that instructional research that is guided by TTI methodology is repsonsive to the question: Given this set of learner characteristics, what is the best way to tailor instruction for this particular type of learner? Hunt (1975) extends this paradigm, asking not only "For whom?" but also "For what purpose?"

Di Vesta (1975) suggests adding another dimension, considering not only individual trait differences, but also the information processing strategies of learners. Generally, individual difference variables have been considered to be useful in adapting to treatment only when measures of individual differences and treatment interact in a disordinal fashion, i.e., when treatment lines cross (Bracht & Glass, 1968). Most early ATI studies used intelligence or other measures of general mental ability and, partly as a result of this, few ATI effects were conclusively demonstrated (Bracht, 1970; Cronbach & Snow, 1969). This led some to question the fruitfulness of this area of research (Glaser & Resnick, 1972).

McKeachie (1974a) characterized the ATI approach as being based largely on the faith that instruction could be improved if it were adapted to individual differences. He believes that there is "some empirical support of that faith" but that most of the recent studies (e.g., Goldberg, 1972) have produced limited results. Despite the pessimistic conclusions of many ATI studies, McKeachie (1974a) believes that

> few citizens, few educators, and not even many researchers would reject the hope that educational environments can somehow be varied in ways that will permit adaptation to characteristics of the developing learner.

This refusal to abandon the ATI concept has resulted in researchers' attempts to refine the approach. Two major refinements in the approach that have implications for the design of instructional strategies are: (1) the rethinking of what is important in terms of aptitudes or traits, and (2) the specification of alternate models of ATI.

The first of these refinements has resulted in part from the failure of researchers to detect significant and consistent interactions using measures of general ability such as intelligence tests. Although early conceptualization of ATI studies (Cronbach & Snow, 1969) had defined aptitude as "any characteristic of the person that forecasts his probability of success under a given treatment" and suggested that new kinds of aptitudes needed to be detected and measured, most researchers have used general ability measures. Berliner and Cahen (1973) have discussed the problem of general intelligence, suggesting that many instructional situations require such a high level of general intelligence that little variance remains in the criterion after the effect of general intelligence is removed. Hence interactions are difficult to detect. They urge finding treatments that do not rely on general intelligence.

McKeachie (1974a) agrees that measures like intelligence tests are "not likely to be effective in discriminating particular interactions...," but that others dealing with changing and less general characteristics may be more useful. Glaser (1972) seems to have been one of the first to note the need for measures of "new aptitudes"--aptitudes that are conceptualized in terms of the processes needed to perform given tasks. He implies that the failure of educators to develop more adaptive instructional techniques has resulted from a tendency to think of students as having fixed, enduring traits rather than ones which are changing and trainable. These "new aptitudes" may include a variety of processes. Some of the more promising ones seem to belong in the categories (information processing skills, cognitive style, and perceptual abilities) mentioned by Hickey (1975). Di Vesta (1973) also feels that ATI studies would be more productive by considering those cognitive processes assumed to be correlated with the traits of processes induced by instructional treatments. In his overview of problems in ATI research, Shapiro (1975) identifies three distinct conceptualizations of mental ability differences which could be used in testing aptitudes:

(1) general mental ability,

(2) finer distinctions such as those considered in models such as Guilford's Structure of the Intellect and hierarchical models in which general ability underlies more restricted abilities,

and (3) problem solving approaches (mental processing, perceiving, coding, storing, and retrieving information).

Several researchers have seen fit to call for the development of new aptitudes which characterize an individual's susceptibility to different educational environments (Glaser, 1972) or which characterize him in terms of "accessibility characteristics" (Hunt, 1971). Hunt describes these latter characteristics as ones that are directly translatable into specific forms of educational environments likely to be effective for an individual's learning. He envisions learner profiles in terms of these characteristics that would describe a learner's:

(1) cognitive orientation

(2) motivational orientation

(3) value orientation

and (4) sensory orientation.

These "accessibility characteristics" would provide a basis for "tuning in" to a person. So far, however, any work in developing such characteristics seems to have been confined to the first area.

A number of researchers (e.g., Salomon, 1972b; Snow, 1970) have discussed alternative models for ATI research. The most recent discussion by Cronbach and Snow (1976) suggests three distinct models which are defined by the manner in which treatments are used. These models are:

(1) the preferential model, which capitalizes on the learner's assets,

(2) the compensatory model, which provides compensation for learner weaknesses,

and (3) the remedial model, which attempts to overcome some deficiency in the learner.

In the preferential model, the treatments are designed to take advantage of the learner's high aptitudes; the compensatory model provides instruction or treatments which accomplish what the learner cannot do for himself; the remedial model attempts to improve learner weaknesses in the processes required for learning under a given treatment.

Although the various conceptual models of ATI may have proven useful, Tobias (1976) feels that another model--the alternative abilities model--that is implicit in many ATI studies has some weaknesses. The assumption underlying this model is that alternate instructional methods draw on different psychological abilities. Tobias, however, doubts that instructional methods can be designed to rely "exclusively" on one set of

abilities or that the abilities required by a task remain constant over the duration of the task. Furthermore, he questions whether abilities or ATI effects generalize over curricular areas and whether it is practical to prepare completely alternative instructional tracks--a task which is easily accomplished in a laboratory but not in a practical setting.

Boutwell and Barton's (1974) review of ATI research also concluded that, "unfortunately, the ATI research has not made any significant impact on the non-laboratory instructional setting." Bunderson and Dunham (1970) have also challenged the ATI concept as a useful predictive procedure in the "real world" because of:

(1) the rarity of disordinal interactions,

and (2) the failure to obtain consistent results in attempts to replicate ATI effects.

Likewise, Allen (1975) could find "little definitive evidence from aptitude-treatment interaction research that points conclusively to the employment of practices that might guide the selection of more general instructional strategies, much less lead to the design of specific instructional media" and felt that any generalizations based on ATI research are "virtually impossible." Allen points out, however, that his paper was limited to "the general aptitude or trait we classify as 'intellectual ability'" rather than the more process-oriented abilities mentioned above.

Even if appropriate abilities are considered, learners can be divided among many uncorrelated lines and, therefore, numerous alternative instructional strategies could be developed (Salomon, 1972b). Furthermore, there remains the basic question, related to the practical application of ATI results, of who should determine which students get which treatments. "Even if the interaction were clearer than it usually is, the task of fitting instruction to the varied students in a typical class may well be too difficult for teachers to perform" (McKeachie, 1974a). Jackson (1970) also argued against the practical value of ATI research because of difficulty in translating treatments into classroom practice. Such information would probably only frustrate the teacher with information he couldn't use.

Regardless of these problems, however, Berliner and Cahen (1973), who have provided probably the most comprehensive consideration of the field, concluded their review on a note of cautious optimism, noting several variables worthy of further investigation as interactive variables. These investigators considered six types of treatment classifications: (1) inductive and deductive, (2) subject-matter, (3) concept-learning, (4) structured and unstructured, (5) treatments involving mathemagenic or questioning activities, and (6) programmed instruction treatment. They draw the following conclusions with regard to each classification:

(1) with respect to inductive and deductive treatments--anxiety, introversion-extroversion, conceptual level, and verbal intelligence are worthy of further investigation; (2) with respect to subject-matter treatments--ATI research should ease debates over which method is best; (3) little attention has been devoted to studies of concept learning; (4) conceptual level of the learner appears important, with respect to structured and unstructured methods; and (5) ATI studies have pointed to the "emergence of limits" for generalizations about the facilitative effects of adjunct questions.

With respect to the sixth area--programmed and computer-assisted instruction--the authors note that

> The results of a substantial number of interaction studies using various aspects of programmed instructional matherials and vastly different traits are completely ambiguous. (p. 81).

They, therefore, urge researchers interested in the area of programmed and computer-assisted instruction to "consider a reanalysis of their field from the perspective of TTI research" (p. 81).

III. Learner Control

Gagné (1971), after presenting the principles contributed by four major learning theorists, suggests that the learner himself is able to put many of these principles into effect.

> This possibility of the learner's contribution to his own learning suggests an even broader theme than any which has been specifically defined by learning theories. Perhaps it may become the most general principle of all.

Merrill (1975) suggests that learner control goes beyond aptitude treatment interactions and that it is an appropriate theoretical methodological alternative to aptitude treatment interactions. Merrill believes that, while the study of aptitude treatment interactions is of interest to a descriptive science, it may be unnecessary for the optimal adaptation of instruction to individual differences and in fact it will not accomplish the goal of adapting instruction to individual differences. After examining the assumptions made by Cronbach and Snow (1973), Merrill suggests alternatives for each of them. Among those challenged is the Cronbach and Snow assumption that the environment should be adapted to the individual, i.e., that the instructor or system decides what treatment is best. Merrill suggests instead that individuals should be given some procedure enabling them to adapt the environment to themselves. What is needed is a "dynamic general strategy" that enables learners to select the particular strategy or tactic that is optimal for their unique configurations of traits at any particular moment. This general strategy should include a wide variety of available tactics as well as techniques for selecting from them. Boutwell and Barton (1974) envision adaptive instructional environments which will use micro-theories of instruction, i.e., theories to explain the behavior of each individual problem solver, as opposed to macro-theories explaining the behavior of general categories of learners. They argue that when a student controls his own instructional strategy, he can develop a personal learning theory (micro-theory) that can be tested. Consequently, they propose adding a new dimension to ATI research--the ability of a learner to control his own environment with regard to his own personal micro-theory.

Dansereau, Atkinson, Long, and McDonald (1974a) imply that a disproportionate amount of emphasis has been placed on strategies for teaching to the exclusion of strategies for learning. With regard to the latter they suggest that

> Training students to construct their own performance-effective strategies is probably even more important than instilling specific techniques or methods.

At the least, they believe that students should know how to choose among available strategies.

McKeachie (1974a) believes that the difficulty of individualizing instruction on the basis of ATI research has made it attractive to hypothesize that students themselves can select the instruction optimal for themselves. Seidel, Wagner, Rosenblatt, Hillelsohn, and Stelzer (1975) have also observed numerous assertions that "learner-controlled instruction can overcome the lack of predetermined, explicit models of instructional practices."

Hunt (1975) notes a trend toward student self-matching and emphasizes the importance of arrangements that permit students to sample a variety of environmental options, what he calls an "environmental cafeteria." He also mentions Glaser's (1973) "browsing model" as an example of the kind of trend that seems to be emerging. These models seem to be at or near the end of a continuum of models for individualizing instruction such as the conceptualization provided by the Educational Products Information Exchange Institute (1974). This conceptualization distinguishes seven models classified as either traditional, diagnostic, or multiple. The models differ in the extent to which instruction is individualized and also in the extent to which learners have control. The models range from the traditional "selection" model, in which each learner in a narrowly defined group is brought to completion of a specific course of study, to the multiple "multimodal" and "multivalent" models. The first of these multiple models offers multiple routes to fixed outcomes, typically leaving the choice of routes to the learner; the second offers multiple routes to various outcomes, typically leaving the choice of routes and outcomes to the learner. A similar classification of types of individual instruction, in which type is based on who determines the objectives and who determines the methods, is offered by Wittich and Schuller (1973). These range from "individually prescribed instruction," in which the student works at his own pace, to "independent study" in which the student determines both objectives and methods. Intermediate to these two extremes are "self-directed" study, in which the objectives are fixed but the learner can determine the methods, and personalized study, in which the student chooses the objectives and then follows a prescribed program.

There are differences of opinion regarding the use and the effectiveness of learner control. Reviewing learner control in the context of computer-assisted instruction, Judd, O'Neil, and Spelt (1974a) characterized the early research as showing positive effects of learner control and the later research as being conflicting. Citing several studies showing positive results for highly motivated and/or highly intelligent subjects, Judd el al. suggest that individual differences should be considered in studies of learner control. In summary, they conclude that "the implications for the utility of learner control in computer-assisted instruction are rather mixed," one reason being the lack of consensus on a definition

of learner control. They believe that the literature suggests the effectiveness of learner control in producing performance and/or affective differences under certain conditions (e.g., sophistication of subjects regarding study techniques)--and that their study showed "complex relationships" between learner control and the individual differences that they investigated.

Optimists on learner control include Lahey and Crawford (1976), who feel that the learner control mode is a "viable technique for providing adaptive instruction" and Dansereau, Long, McDonald, and Atkinson (1975a), who see information processing or learning strategies as possibly "more fundamental determinants of learning performances than actual abilities." Glaser (1972) contends in his discussion of the "new aptitudes" that "the traditional measures of general ability and aptitudes err on the side of assuming too much consistency, and deemphasize the capability of individuals to devise plans and actions depending upon the rules, needs, and demands of alternative situations." Others are somewhat more guarded in their stances toward learner control, believing that the effectiveness of learner control is not clear or the results related to it are inconclusive (e.g., Atkinson, 1972; McKeachie, 1974a). Some researchers (e.g., Beard et al., 1975; Dansereau, Evans, Wright, Long, & Atkinson, 1974b; and Glaser, 1973) feel that learner judgment is but one of several items of information that should be used in making instructional decisions and that it is unlikely that there will be pure cases of either learner-determined or instructor-determined instructional sequences.

Still others see little merit to a learner-controlled approach because "...its advocates are trying to avoid the difficult but challenging task of developing a viable theory of instruction" (Beard et al., 1975). Atkinson (1972) questions student judgment, reporting some evidence that students tend to choose suboptimal learning strategies that compare unfavorably with program control. McMullen (1975) questions their motivation and urges restrictions on learner control, suggesting that "when given the option to put off demanding intellectual effort, students appear to take the option..." and that the majority of students tend to perform better with the help of optimization procedures to tailor learning experiences. Beard, Lorton, Searle, and Atkinson (1973) tend to support this contention, finding that students did not choose to exercise much control over the material that was presented to them, choosing instead to follow the path of the ordered lessons. The particular curriculum studied, however, was laid out in a sound order and thus did not encourage students to make different choices. They suggest the possibility of a CAI program having no automatic sequencing, i.e., one in which the student must choose the order of presentation. Trown (1975), studying personality-treatment interactions using treatments characterized as either inductive learner-centered exploratory or deductive teacher-centered supportive, noted a significant strategy-anxiety interaction and thus contended that "some, but by no means all, children remember more when they are 'set free' to learn."

Merrill (1975) echoes Trown's sentiment, suggesting that there may be learner traits which enable students to benefit differentially from learner control, and Judd, Daubek, and O'Neil (1975) note that students' ability to use learner control effectively appears to be a function of personality traits as well as cognitive skills.

The work of Tobias (1976) suggests one individual difference variable, prior familiarity with subject matter, that he feels consistently interacts with instructional treatment. Tobias cites a number of studies that suggest the general hypothesis that the higher the level of prior achievement, the lower the need for instructional support (i.e., providing structure such as organizing and editing material, not merely presenting it). Evidence for this instructional support hypothesis is given by Salomon (1974) in studies in which low ability students benefited most under an instructional support condition in which they were shown the skills to be acquired, while high ability students performed better under minimal support conditions. This suggested that training may have interfered with the students' own effective skills. Possibly, it is unwise to force assistance on students, at least those possessing relevant abilities in sufficient quantity. A study reported by O'Neil (1972a), in which memory support provided at the option of anxious students, was superior to a mandatory support condition, illustrates this point.

One individual difference variable that might, logically, be thought to be related to learner control is "locus of control," i.e., the learner's perception of his degree of control over his environment. Reynolds and Gentile (1975) reported results suggesting a possible interaction between locus of control and opportunity for control (self direction or external control) that was opposite to the hypothesized direction. That is, externals performed better when given the opportunity for self direction, while internals did better under external control conditions. Judd, O'Neil, and Spelt (1974b), however, while able to predict individual differences in learner control behavior with the Achievement via Independence scale of the California Psychological Inventory, could not with Rotter's Internal-External Control Scale. A recent study by Crist-Whitzel and Hawley-Winne (1976) gave some evidence of an interaction between instructional treatments (including Individually Prescribed Instruction and a traditional approach centering on the use of a basal text) and locus of control, in which internals did slightly better under the traditional approach. It seems reasonable to attempt to explain this difference on the basis of amount of control over instruction that students had. These studies are illustrative of research using locus of control as a variable. Since the overwhelming majority of studies of locus of control have demonstrated positive relationships between internality and academic achievement (Lefcourt, 1972), further studies using locus of control and learner control

seem to be indicated. We are reminded here, however, of Cronbach's (1975) statement that the special ability hypothesis got off on a wrong start in ATI studies. In other words, to hypothesize that internals would perform better under learner control conditions might be getting off on the wrong foot again.

There may be other individual difference variables related to instructional treatments that interact with learner control. Fry (1974), for example, reports that learner control of the sequence of questions they could ask (expert-determined, learner-determined, or random) interacted with inquisitiveness. For high aptitude students, inquisitive ones performed better under the learner control condition, while the expert-determined sequence was better for low inquisitive students. This may again suggest that, given the present state of the art of instructional design, when learners possess a relevant ability, it may be better not to tamper with it.

It is also important to consider the effects of learner control with respect to noncognitive, as well as cognitive, outcomes. For example, Pascal (1971) reports that students given the type of instruction they preferred (lecture, lecture with discussion, or independent study) developed more positive attitudes toward the subject, psychology. There was no effect on achievement, however. Hansen (1972) found that learner control subjects showed a decrease in state anxiety during a CAI course on an imaginery science.

There may be a number of reasons for the effectiveness, under certain conditions, of learner control. One view of student control reasons that, given the capability to perform a task, any benefits are due to increased motivation, which learner control is assumed to provide. This view has been stated by several including Beard et al. (1975) and Bunderson (1974). Although learner control may provide increased motivation, its effectiveness probably depends more on the effectiveness of the variables that the learner controls. Judd et al. (1974a) investigated four treatments defined by availability of learner control and an instructional aid (mnemonics); they found that learner control did not have a facilitating effect primarily because the mnemonic aid was not helpful.

Gay (1969) investigated learning mathematical rules under three conditions differing in the number of examples given and found a significant sex by treatment interaction. Males performed better when allowed to determine the number of examples provided. Females performed better in a variable example group, in which the number of examples presented for each rule was based on the subject's predicted optimal number. Possibly, females' behavior was more predictable in this context. McKeachie (1974a) cites Atkinson's (1972) research as illustrative of the fact that:

> when one's theory of learning is good enough, takes account of individual differences, and is adjusted in terms of immediate past experience, planned instruction can be superior to random order or student-selected presentation.

These studies suggest that providing learner control may be the most appropriate instructional technique in the absence of a more appropriate theory. Zinn (1970) agrees that learner control is "likely to be of immediate success because the author gives up control where he is not sure of his prescription for the student," and that "in some situations, programming the computer to the initiative of individual learners may be the best strategy."

Related to learner control is the issue of preference. The preferential model has been mentioned above in connection with ATI studies. This model seems to assume implicitly that preference and aptitudes are synonymous, i.e., that students prefer to use a strategy under which they perform best. Hunt (1975), however, feels that the major problem in student self-assessment is "...distinguishing between the environment a student requires and the one he prefers." Dansereau et al. (1974a) consider a learner's "reception preference" as somewhat more specific than cognitive style; they consider his "educational set" as a predisposition to learn certain types of material (e.g., either facts or concepts).

There is some evidence suggesting that when given control: (1) learners show preference for particular strategies, (2) there is considerable variability in strategies, and (3) styles are stable across learning tasks. Lahey and Crawford (1976) report wide variability in selection strategies when learners were given control over the sequence of presentation and level of difficulty of rules, examples, and practice in a CAI course in basic electronics. They also showed definite preferences, the rule-example-practice strategy being selected most frequently. Hartnett (1976) found that in learning a second language by either a deductive or an inductive method, students were capable of choosing the method that was optimal for them on the basis of preference. An interesting physiological finding was that preference for method was related to hemisphere preference as measured by eye movements. White and Smith (1974) report a difference between "intuitive" and "sensing" personality types in their preference for learner control, leading the authors to suggest beginning CAI lessons with modules to identify these types. Pask and Scott (1973) describe a CAI system (CASTE) that determines a student's preferred learning strategy by engaging him in a dialogue about his learning.

Elliott (1976) suggested that adult learners' styles (i.e., the manner in which learners approach learning) are stable across learning tasks. Style was determined in Elliott's research by sequence, pacing, type of move (rule, example, or practice) and level of difficulty in a CAI lesson (given on the PLATO IV system) dealing with metric conversions.

It seems possible that, just as learner control may interact with individual differences, it may also be differentially effective at different stages of learning. McMullen (1975) suggested that learner control was better than program control at certain points in the exercise. The investigation of learner control effects at different stages seems appropriate in light of previous research (e.g., Fleishman, 1962, 1967) showing that the pattern of abilities contributing to performance changes with practice and that factors arise which are specific to stages of learning. Tobias (1976) suggests that indeed one of the problems with the alternative abilities ATI model is our lack of knowledge about the temporal consistency of abilities required by the task.

A recent review of student-control of learning, which is provided by George (1976), is helpful in focusing on learner control, not so much by the comprehensiveness of the review (16 studies), but by the general classification scheme the author provides. In his attempt to help researchers establish a taxonomy for investigating individualized instruction and, in particular, student-control of learning, George (1976) sets forth the following broad categories:

(1) programmed instruction,

(2) instructional objectives,

(3) learning activities,

and (4) performance standards.

Illustrative of studies in each area, respectively, are:

(1) studies in which students were allowed to organize programmed instructional materials (e.g., Allen & McDonald, 1966; and Campbell & Chapman, 1967);

(2) studies in which students could choose objectives (e.g., McEwen, 1972);

(3) studies in which students could exercise control over learning techniques or methods (e.g., George, 1973);

(4) studies in which students were allowed to determine their own performance standards and/or reinforcement contingencies (e.g., Glynn, Thomas, & Shee, 1973).

It is interesting to note, however, that computer-assisted instruction is not considered as a category in this review, although it seems to be the area holding the most promise for learner control. O'Neal (1973), for one, believes that any environment needed to support a learner control model must rely heavily on CAI and CMI and that sophisticated hardware is required. Efforts to introduce learner control in CAI have been increasingly sophisticated. Rockart, Morton, and Zannetos (1971) describe an interactive computer-assisted instruction system allowing students to ask questions of the data base. The primary learner control feature was the student's option to follow his own path to learn the material if he considered the instructor's path to be ineffective. Fine (1972) attempts to define and describe an increasing number of sophisticated commands that have been, or could be, modified to provide learner control. Many of these are now available to the learner using the TICCIT system (MITRE Corportion, 1974; O'Neal, 1973).

In summary, it appears that learner control is a potentially useful instructional tactic, but that a good deal of research in the area is indicated. In reviewing research studies which investigated the propositions underlying the Instructional Strategy Diagnostic Profile (ISDP) developed by Merrill and Wood (1974), Merrill, Olsen, and Coldway (1976) could find no studies to support the two ISDP propositions related to learner control--that the learner should be able to control the amount and sequence of exposure to rules, examples, and practice and that he should be able to locate, skip, or review a given form of presentation. Seidel et al. (1975) also observed "little systematic exploration of the nature and degree of desirable learner-generated control processes in an adaptive teaching system."

Nonetheless, a trend towards learner control is evident to many, including Hickey (1975), who concluded one section of his review with the statement that "all of these new directions in instructional applications of computers exemplify an emerging new emphasis: <u>control</u> for the student."

Finally, it has been suggested (e.g., Judd, 1973) that learners may need specific training to exercise effective control over their own instruction.

IV. Training/Modification of Learner Traits and Strategies

The remedial ATI model discussed earlier assumes that aptitudes are in some way able to be modified. A number of authors have been concerned with this problem, Glaser (1972) asking, for example, "how can an individual's abilities be modified and strengthened to meet the prerequisite demands of available means of instruction?"

In their review of trait-treatment interactions Berliner and Cahen (1973) imply an obligation to train abilities, questioning philosophically,

> should instruction that is guided by TTI research capitalize solely on the strengths of the learner or is there an obligation to develop traits within the learner that would allow him to succeed at many types of tasks under many types of instruction?

Gagné (1974) presents a classification scheme consisting of the following five categories: (1) verbal information, (2) motor skills, (3) intellectual skills, (4) attitudes, and (5) cognitive strategies. Referring to these categories, he prefers to use the term "learned capabilities" instead of abilities, implying their susceptibility of training. Glaser and Resnick (1972) make explicit reference to aptitude training as a means of adapting to individual differences, suggesting "the possibility of direct training of aptitude or cognitive styles thought to be called upon in instruction." They report, however, that "only a limited number" of studies have been conducted in this area. Examples include attempts to modify the behavior of impulsive children in the direction of more reflectivity (cognitive styles) and efforts to train perceptual abilities. The authors note that there have been far fewer studies attempting to train psychometrically defined abilities than there have been to develop Piagetian concepts, suggesting that Piagetian theory's concern with developmental changes has suggested a number of performances on which instruction might be focused. These performances are more nearly what Glaser (1972) has termed "the new aptitudes," i.e., process variables. Piaget's work supports Glaser's (1972) theme of the importance of modifiable behavioral processes as opposed to fixed aptitudes, since it suggests that major changes in children's modes of thinking mark various stages of development. Glaser's (1972) final recommendations include the teaching of both self-managment skills (or "learning to learn" skills) and basic psychological processes.

With respect to cognitive styles, Dansereau et al. (1974a) believe that most researchers have assumed them to be relatively fixed and, consequently, have made only a "few scattered attempts" at modifying style through training. Yet the authors note the "apparent superiority

of some styles" and suggest that explorations into training these styles should be undertaken. Examples of cognitive styles they cite include category width, cognitive control, and field dependence.

Recently, however, a "spurt of interest" in analyzing the cognitive processes that contribute to intelligence or "aptitude-like" performance has been reported (Glaser, 1976). Numerous authors (e.g., Frase, 1975) have cited the success of the instructional engineer at analyzing the critical components of a task and the specific capabilities and skills of the learner as being essential to optimal instructional design. The early work of Gagné (1967) suggested a number of abilities underlying problem-solving performance, such as the ability to recall relevant rules and the ability to generate hypotheses. Hansen and associates (1973), however, report that "the current state-of-the-art allows only a very tentative statement of an optimal instructional strategy for teaching problem-solving behavior."

A variety of researchers have attempted to provide training on the tasks found in intelligence tests. Several studies have reported gains after training on selected tasks such as digit span and letter series completion problems (Estes, 1974; Holzman, 1975; Hunt, Frost, & Lunneborg, 1973). Lyons (1975) has carried the analysis of intelligence even further, arguing that current definitions of intelligence in terms of performance on a selected set of tasks are inadequate for those wishing to design environments to enhance cognitive abilities. He attempts to isolate the mental processes that underlie individual differences on one of these tasks, digit span. While he was able to rule out a number of processes, his final conclusion was that more research is required to pinpoint the exact processes. Whitely (1976), investigating facility in solving verbal analogy problems, was forced to conclude that "solving analogies does not depend on individual differences in some major aspects of processing relationships." The Structure of Intellect (SI) model proposed by Guilford (1967), in which 120 separate abilities, defined by content, operation, and product, are hypothesized, offers a number of traits on which training could be concentrated. Guilford and Hoepfner (1971) suggest the possibility of prescribing special intellectual exercises to remedy learner weaknesses in specific abilities. Dansereau et al. (1974a) have suggested the use of SI tests to diagnose deficits in skills required for selection and implementation of learning strategies. Dansereau et al. (1974a) related the SI operations of cognition, memory, divergent and convergent production, and evaluation to processes that the learner requires in new task situations (i.e., task perception, strategy generation, strategy selection strategy implementation, and strategy evaluation. They have also urged training in putting these skills together in an overall strategy utilization process.

Glaser (1976) suggests analysis contrasting the skills of competent performers and novices as a kind of research helpful to understanding competence. Dansereau and his associates have been heavily involved in

the identification and training of learning strategies. They identify two general options for strategy training (Dansereau et al., 1974a). The first is intensive training in a separate course (e.g., speed reading and study skills courses); the second option is training within the context of regular courses.

In order to identify trainable learning strategies used by students, Dansereau et al.(1975a) developed and administered a learning strategy inventory from which they were able to identify four phases of the learning process that could be incorporated into a strategy training program. These were:

(1) identification of important and unfamiliar material,

(2) application of techniques for the comprehension and retention of identified materials,

(3) efficient retrieval of information under appropriate circumstances,

and (4) effective coping with internal and external distractions while the processes are occurring.

Focusing on (2) above, Dansereau et al.(1975b) developed a training program to teach selected specific strategies including three alternative comprehension/retention strategies. These strategies involved a question-answer technique, in which students were trained to ask their own "high level" questions after short segments of text; a paraphrase technique, in which students were trained to generate their own summary-like reviews and organizers in the form of paraphrase; and an imagery technique, in which students were asked to draw or verbally describe the visual image they have created to capture the main ideas of the material (Dansereau, Long, McDonald, Atkinson, & Collins, 1975c, 1975d, 1975e). The researchers also provided some training in techniques to retrieve stored information (when to attempt it, what cues to use, what steps, etc.) and experience in coping with distractions during learning. The investigators believe that their project was "very successful" in accomplishing its goals. Earlier Dansereau et al. (1974b) had also suggested that, since most educational material has not been optimally organized, it seems reasonable to train students to reorganize this information to suit their own cognitive structure. They also suggested the possibilities of (1) training students to be more conceptually oriented and (2) training students to adopt a more "internal-like" view of the world (since locus of control shows such a strong relationship to academic achievement). Rigney (1976) indicates his belief that cognitive strategies can, to some extent, compensate for low capacity. He also feels that what he calls "detached strategies" may be more appropriate for bright students, who may be more

able to provide their own direction, while "embedded strategies" might be more effective with less able students, who may need simpler orienting tasks and more support and encouragement. Rigney (1976) also envisions the possibility of teaching student's to exercise better control over "attentional and intentional processes" by using neurophysiological indicators (e.g., biofeedback techniques), particularly to reduce self-generated distractors during learning.

The compensatory model of ATI requires either providing learners with the necessary mediators, organization, modality, etc., which they, presumably, cannot provide for themselves, or circumventing the debilitating effects of certain traits or states (Salomon, 1972b). In connection with the compensatory model Salomon (1970, 1972a) discusses a process he calls "supplantation," i.e., replacing or supplanting a covert mental operation already in the learner's repertoire but which he would have to activate on his own. An example is an audiovisual treatment in which the camera "zoomed in" on details, thus helping the learner focus on these. Salomon (1972a) found that low verbal reasoning students were able to benefit from this process. More important, he suggests possible benefits of training students on "pictorial conventions" such as "zooming," slow motion, and object rotation so that they might activate these on their own when processing information from pictorial presentations.

Atkinson and Raugh (1974) report using a mnemonic technique, called the keyword method, for learning a foreign vocabulary. Their research shows that the two-stage method, which provides both an acoustic link (keyword) and an imagery link, was effective in learning Spanish and Russian vocabulary. Their research shows that providing learners with a "new aptitude" or strategy (which is relatively simple) can affectively increase learning.

Besides providing learners with relevant abilities, helping them to overcome any debilitating traits or states may be equally important. Berliner and Cahen (1973) mention trait modification or shaping (e.g., reducing the level of authoritarianism) as a way to deal with learner traits.

One of the most frequently studied debilitating learner traits (or states) is anxiety. The relationship between anxiety and performance is complex, as numerous studies have revealed (e.g., Leherissey, O'Neil, Heinrich, & Hansen, 1973; O'Neil, 1972b; Tobias & Abramson, 1971). For those instances in which anxiety has been considered detrimental, two general approaches have been advocated. The first approach attempts to remove anxiety, while the second seeks to provide aids to overcome the specific damaging properties of the trait. Sarason (1972) was able to reduce text anxiety and improve the performance of high test anxious subjects by providing reassuring instructions. Leherissey, O'Neil, and Hansen (1971), arguing that the disruptive effect of anxiety is through

its affect on memory, tried with limited success to provide memory support to anxious students in the form of a list of previous errors. Wine's (1972) observations of high and low test anxious subjects revealed that anxious children were more alert to evaluative cues (sought teacher approval, etc.) before an examination, while low anxious subjects were more alert to cues more directly related to the task. The two studies mentioned above (Leherissey et al. (1971) and Wine (1972)) are illustrative of two attempts to analyze and modify a learner trait in order to enhance learning.

V. Adaptive Instructional Models/Strategies

The theme of this section has been captured by Glaser's (1972) questions: "How can an educational environment be adjusted to an individual's particular talents, and to his particular strengths and weaknesses...?" and "How can knowledge of an individual's pattern of abilities and interests be matched to the method, content, and timing of instruction?" Hansen et al. (1973) provide definition to the term "adaptive," which to them suggests the continuous tailoring (or adaptation) of instructional task factors, materials, and resources in order to match the changing instructional needs, skills, and interest motivations of individual students. Mitzel (1970) lists eight capabilities that he feels an adaptive system should have. It should

(1) be individually paced,

(2) begin and end lessons when convenient,

(3) consider past achievement,

(4) provide the preferred type of reinforcement for each individual,

(5) provide the preferred mode of presentation for each learner,

(6) diagnose and remedy skill deficiencies,

(7) consider immediate past history of responses,

and (8) use the optimal presentation strategy for each trainee.

Boutwell and Barton (1974) envision new adaptive instructional environments that will:

(1) adapt to the student's entering aptitude level,

(2) train a learner to develop his own cognitive abilities,

and (3) adapt instruction to subsequent improvements in student aptitudes.

Early attempts to individualize or adapt instruction on the basis of individual differences may have been overly ambitious, guided by researchers like Cronbach and Snow (1969), who urged designing enough treatments so that everyone would be able to succeed at one of them.

In practice, though, there was relatively little real individualization. With respect to CAI, for instance, Bushnell (as reported by Parkus,1970) told a commission that most CAI systems do little more than "dispense instruction in a fixed, preprogrammed sequence of graded instructional material... designed to perpetuate standard classroom procedures." Essentially, individualization was equated with the pacing of instruction or speed of learning (Wittich & Schuller, 1973). There appear to have been barriers even to this degree of individualization. Hitchens (1971), speaking about individualization of training in the military, stated that the trend had been underway "for some time." One of the problems cited, however, was differences in learning rates, prompting him to ask: What do you do with a recruit if he finishes a 14-week course in 12 weeks? Assign him to K.P.?

More recently, Boutwell and Barton (1974) have noted the failure to adapt instruction, concluding after reviewing the ATI research, that educators have failed to individualize instruction based on student aptitudes. Technical training courses such as those used in the military provide no exception, prompting Feureig, Lukas, and Benhaim (1975) to conclude that:

> In their current form, most technical training courses are designed for a nonadaptive presentation. The content and sequencing are essentially the same for all students.

They feel that, as a result, the effective application of adaptive training models will require substantial extension and restructuring of existing courses.

The sequencing of instruction is often associated with attempts at individualization. Pask (1971) developed a course network model to guide the selection of path sequences. He showed that matching the structure of the learning program to the student's learning strategy results in more effective instruction than learner control. Pask (1971) considered instructional prerequisites but did not consider student learning ability, except to classify learners as "serialists" or "holists." But Slough, Ellis, and Lahey (1972) studied the effects of branching techniques and concluded that sophisticated techniques are of little value without instructional content that is sensitive to student traits. Atkinson (1972) encourages the development of what he calls response sensitive paradigms to meet this need. An interesting early development with respect to such paradigms is the work by Smallwood (1963), who in designing procedures for selecting and adapting instructional paths, presented a decision structure that uses both the individual student's response history, as well as the cumulative history of students who previously took the course. Hansen et al. (1973) provide an important contribution, distinguishing between pretask and within-task adaptation. Whereas pretask adaptation uses premeasures to diagnose and prescribe

instruction, within-task adaptation applies intermediate evaluations of a student's progress within the instructional sequence in order to prescribe instruction to correct errors. Thus the latter technique makes decisions based on an updated, cumulative response history, not just on the last response in the sequence as earlier techniques did. Hansen et al. (1973) cite several studies that show that trait or state variables measured prior to the learning task are not as effective in predicting student performance as those measured during the learning task itself.

Boutwell and Barton (1974) also recommend measurement of students' cognitive style in solving task problems. They suggest a monitoring function that records every problem-solving decision attempted. This information is, in turn, relayed to an adviser function, which interacts in a tutorial manner with the student. Theoretically, the learner then modifies his style and attacks the problem with "a superior cognitive style."

In reviewing the state-of-the-art developments in adaptive instructional models, Hansen et al. (1973) identify several models and recommend five of them for immediate implementation. One model that is described is termed the "complex tutorial" model, one that uses between-task adaptation in order to update instructional strategies for rule learning and problem solving. This model is described as one in which

> The specification of instructional strategies for subsequent rules will be based on the student's performance under previous instructional strategies. It is anticipated that, through the use of this iterative cybernetic-adaptive procedure, an optimal instructional strategy of rule-learning for a given student will be approximated over a short series of rules.

This between-task model is thought to permit a more complex decision structure.

Hansen et al. (1973) specify eight types of input that the complex tutorial model would have. These are:

(1) difficulty level of a given rule,

(2) difficulty level of examples,

(3) number of rules in a series,

(4) entering cognitive abilities such as general and inductive reasoning,

(5) preinstruction retention index,

(6) learning style, such as dogmatism and modality preferences,

(7) within-task performance measures such as display latency, number correct, and response latency,

and (8) within-task state variables (e.g., anxiety and subjective confidence).

Hansen et al. (1973) are careful to mention, however, that this model "...contains many innovative features which have yet to be implemented and validated."

The other adaptive instructional models (and their functions) recommended by Hansen et al. (1973) included:

(1) the drill-and-practice model (increases speed and proficiency),

(2) the concept acquisition model (promotes concept attainment by varying the sequence, amount, and kinds of examples),

(3) the complex tutorial model (provides the student with strategies with which to master rule-learning and problem solving),

(4) the algorithmic regression model (details a plan of instruction for each student in form of a prescription, assigns resources, provides incentives, and monitors outcomes for input into the next individualized prescription),

and (5) dynamic programming (a master instructional model that is capable of incorporating the previously mentioned models in order to optimize student progress, proficiency, and instructional resources).

Two other models--the natural language processing model and the automaton model--were recommended for further research before field testing.

Kingsley and Stelzer (1974) developed an initial theoretical basis for individualized instruction by formulating an axiomatic model (based on axioms, definitions, and theorems). They present an overall theory of instruction relating student state theory and subject-matter structure theory. Central to their formulation is a model representing the state of the student at any point in time.

The model developed by Feureig et al. (1975) considers "in a detailed manner" the individual trainee's learning abilities and the instructional objectives as these interact. This detail includes the use of a measure of general learning ability as well as ability measured by the specific test items employed to measure the course objectives. The result is an "ability vector" that is both "history sensitive" and "context sensitive." In preparing instructional materials to be used in this model, abilities that are specific to the task are isolated. For example, the ability to solve algebra word problems involves both the ability to manipulate words and the ability to manipulate numerical expressions. A flavor for the model is provided in the words of its developers:

> Overall operation of the model is as follows: The student progresses through material, gradually augmenting his ability vector, satisfying prerequisites grouped in sets, and progresses to higher levels of instruction where the process is repeated. The "student performance/history logger" computes and stores performance on subtasks and the "performance predictor" computes the expected performance on various path segments possible from the student's current mode. The "path optimizer," using this result along with the requirements for satisfying threshold set requirements, selects the optimal next path.

The entire model depends, though, on the fundamental assumption that courses can be structured as sequences of concepts each having prerequisite subconcepts and that these sequences can be realized in many different paths depending on individuals as well as the type of instruction. An evaluation of the model, in which subjects were sequenced through both minimal and maximal paths, showed the model to be effective in reducing course time. It was especially effective, however, in enchancing the learning of less able students and in remediating prerequisite deficiencies.

R. C. Atkinson and his associates have lead the attempt to bring optimization procedures to computer-assisted instruction. Atkinson recommends the goal of maximizing the average percent correct at posttest, subject to the constraint that the variance of the average be no longer than if CAI had not been used. As reported by Cotton (1976), Atkinson and his colleagues have applied optimization procedures to both the CAI sequencing of items and the allotment of computer instructional time for spelling, reading, and foreign languages. Not all of the optimization procedures investigated have proved effective, however. Wollmer and Bond (1975), for example, tested a Markov model for optimizing hierarchical learning for two CAI programs in electronics and trigonometry. They reported that the model was not suitable for optimizing instruction in terms of developing instructional sequences to minimize overall time.

There have also been advances in individualizing technical training. Illustrative of these attempts are efforts reported by Rigney, Morrison, Williams, and Towne (1973), McGuirk and Pieper (1974), and Reidel, Abrams, and Post (1975).

Rigney et al. (1973) investigated the use of an individual trainer for training radar intercept operators (RIO). In the context of the adaptive models listed by Hansen et al. (1973), the mode employed here was drill-and-practice to develop speed. The major features of the instructional strategy used were (1) the simulation of enough features of the job to provide realism, (2) the provision of a static (stop action), as well as a dynamic, mode, (3) immediate feedback, (4) different categories of problems, and (5) trials-to-criterion logic which automatically moved the student to the next level or back to a previous level.

In assessing their approach Rigney et al. state that

> we regard this particular implementation as a relatively crude beginning. As basic research now underway by many investigators develops more knowledge about cognitive structures and human information processing, and more powerful computer programming techniques for manipulating these structures and processes in the context of CAI, we can expect to see exciting advances in the effectiveness of training procedures. (p. 63)

An evaluation of a general purpose simulator by McGuirk and Pieper (1974) suggests the promise of simulators for individualizing instruction. Comparing "actual equipment trainers" (AET) with simulators, they note that AETs have neither the capability to maximize student interaction (reinforcement, feedback, etc.) with equipment nor the ability to automatically record responses--conditions which are viewed as necessary for an adequate training device. The comment by one instructor in the weapons control system mechanics course captured the enthusiasm generated by the simulator:

> I have over 18 years experience as an instructor and for the first time have seen a way to self-pace (individualize) systems avionics training. The cost of our trainers...alone forces us to use the lock-step or group-paced method of instruction. With sufficient simulators...we could easily self-pace the avionics program.

Reidel et al. (1975) compared adaptive and nonadaptive strategies over a range of difficulty levels for a complex psychomotor task on an arc welding simulator and found that adaptive and fixed strategies were equally effective. Subjects used a hand-held tracking stylus that emitted a signal when they deviated from set ranges for each of several adaptive variables, including distance from stylus tip to surface, tracking width tolerance, and stylus attitude (angle) tolerance. In the adaptive condition, machine tolerances were either relaxed or tightened depending on whether the subject showed deterioration or improvement, respectively. The investigators

suggested that adaptive techniques may not have been appropriate because of the complexity of the task, hypothesizing that, for complex tasks, adaptive variables may begin to interact with each other so that any overall gain is lost. Since the effects of interactions of adaptive variables in a complex psychomotor task have never been determined, the authors suggest investigating their effects first separately and then in combination.

Finally, the work of Scheurerman (1976) has contributed to the field by developing three quantitative indices to measure the quality of the adapting features of a curriculum. These indices allow one to distinguish between programs that appear to be adaptive and those that really are. These three indices are:

(1) the consequence ratio (the ratio of the amount of time the student would spend if he failed the diagnostic test, i.e., the consequence time, to the sum of the testing time and the consequence time),

(2) the predictive validity ratio (the ratio of correct to total predictions),

and (3) the discriminability ratio (the ratio of the number passing, or failing, the diagnostic test, whichever is smaller, to the total number taking the test).

The first measures how much time is actually saved if the student passes the diagnostic test; the second reflects agreement between the diagnostic test and the mastery test in the absence of any intervening instruction; and the third reflects the extent to which diagnostic procedures reflect individual differences.

VI. Designing Instructional Tasks

Several authors have suggested that the design of instruction should begin with a task analysis (Cronbach & Snow, 1976; Rhetts, 1974; Shapiro, 1975). Frase (1975) reviews a number of studies that

> support the general point that a careful analysis of the structural characteristics of a task reveals ways of improving the form of instruction. (p. 59)

Clark (1975), however, contends that expansion in the development of new measures of ability is "offset by the lack of a parallel increase in efforts to augment our knowledge about treatments" (p. 198).

Merrill and Boutwell (1973), proposing a taxonomy of task variables, suggests that

> Perhaps the most salient factor in the paucity of research in this area (instructional development) is the lack of any systematic identification of those variables that are manipulated by instructional developers.

Clark (1975) cites a number of authors who also believe that our current methods for characterizing treatments are primitive. Shapiro (1975) suggests that the simplest way to organize the universe of treatments is by the vehicle through which instruction is conveyed (e.g., teacher, computers, television) and within which there are differentiations. For example, computer-assisted instruction can be characterized by step size, type and amount of student response, amount and direction of branching, level and order of concept presentation, ratio and order of rules and examples, number and placement of illustrations, and mode of presentation (e.g., teletype or cathode ray tube). Clark (1975) urges more concern with the relevant attributes of treatments. For example, instead of describing the instructional vehicle as "television" Clark would prefer to describe it in terms of relevant attributes such as its capability to show objects in motion, in color, in three dimensions, etc.

Clark (1975) mentions two general approaches to developing taxonomies of media attributes. It seems that these two approaches--reasoning from trait systems or reasoning from process descriptions--may also be useful in instructional design attempts. One of the best known trait systems is Guilford's (1967) structure of the intellect model. Peterson and Hancock (1974) reasoned from this system to develop instructional materials representing Guilford's semantic, figural, and symbolic content modes.

Siegel and Bergman (1974) also used Guilford's model, developing eight readability/comprehensibility constructs based on the structure of intellect factors. These constructs were thought to have advantages over previous measures of readability because they stress abilities required for textual comprehension rather than the structural aspects of the material. These constructs were applied to textual material that loaded differentially (high or low) on these constructs, and the material administered to Air Force personnel. The authors concluded that textual material could be made more comprehensible by deemphasizing certain constructs (e.g., cognition of semantic units) and by providing others (e.g., semantic implications) rather than requiring the reader to form his own. Unfortunately, this research seems to have neglected individual differences in subjects' ability to deal with the various constructs. Both of these efforts, however, are illustrative of attempts to develop instructional materials that relate in meaningful ways to formally-specified cognitive constructs.

Other attempts have used the second approach, i.e., reasoning from descriptions of the processes required to succeed at instructional tasks. Illustrative of this approach is a study by Cromer (1970) in which reading materials were presegmented. This technique helped poor readers, provided they had adequate vocabulary knowledge.

Elliot (1976) developed a model to optimize learning (a model for combining trait-treatment interaction theory and instructional design). Investigating concept learning in third grade students, Elliot concluded that his data partially supported the theory that an instructional treatment can be specifically designed to match the cognitive style of learners. He presents two essentially compensatory procedures. The first procedure--isolating concept attributes by using different colors to highlight them and presenting examples sequentially--was designed to help field dependent subjects. The second procedure used advance organizers and instructions to "look carefully at each example" to help impulsive subjects.

Earlier, Bunderson and Dunham (1970) had suggested a different way to use aptitude-treatment interactions. Instead of seeking disordinal interactions in order to assign learners to treatments, they suggested using ATIs to revise "optimal" treatments in order to help slow learners. Hansen et al.(1973) followed this procedure. Instead of developing entirely different alternative instructional procedures, they designed what they believe to be the optimal treatment, using the most efficient sequence, the most effective instructional examples, etc. Adaptation then occurred within this program.

Finally, one of the most ambitious attempts to translate ATI findings into prescriptions for the development of instructional products is presented by Allen (1975). He first develops a set of tentative generalizations based on the available research. These generalizations take the form of 28 statements of instructional procedures that seem to either help or hinder

high-, middle-, and low-ability students. From these statements come prescriptions thought to be useful for designing instructional media. A number of specific techniques are suggested for (1) motivating students and establishing learning sets, (2) directing attention, (3) eliciting participation, (4) correcting or confirming responses, (5) pacing, (6) replacing or supplanting mental processing operations, (7) organizing content, (8) establishing appropriate levels of information density and complexity, and (9) requiring the manipulation of material. It appears, therefore, that ATI research has made at least a modest impact on instructional design.

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